

# Forage sorghum-legumes intercropping: effect on growth, yields, nutritional quality and economic returns

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**ABSTRACT:** Cereal-legumes intercropping is among the most economical and effective agronomic strategies to boost forage biomass production, nutritional quality and monetary returns. This review synthesizes the research findings on how intercropping affects productivity, quality, competitiveness and economic viability of sorghum-legumes mixed, row and strip intercropping systems under varied pedo-climatic conditions. Though component crops show yield reductions in row (additive and row-replacement series), mixed (seed blended crops) and strip intercropping systems, in general overall productivity per unit land area increases to a great extent. The significantly higher resource capturing with better utilization efficacy by intercrops in temporal and spatial dimensions helps explain their greater productivity. In addition, forage intercrops result in improved nutritional quality as legumes contain protein in double quantity than cereals. Cereal-legumes intercropping systems yield

higher quantities of lush green forage with improved quality traits, which ultimately increase monetary benefits. Furthermore, legumes inclusion as an intercrop with cereals has the potential to serve as a nitrogen-saving strategy due to the biological nitrogen fixation (BNF) process. Moreover, cereal-legume intercropping systems are effective in reducing weed infestations and soil erosion by providing extended soil cover, as well as in increasing water use efficiency and improving soil fertility. However, despite a significant increase in overall productivity, component crops suffer yield losses in intercropping systems owing to competition for the finite divisible pool of growth resources. Thus, there is a dire need to optimize spatial and temporal arrangements in sorghum-legumes intercropping systems to achieve maximum productivity and economic returns.

**Key words:** benefit-cost ratio, economics of production, forage quality, land equivalent ratio, row replacement series.

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## INTRODUCTION

Forage intercropping integrates crops and livestock production because forages can be grown as intercrops with grain crops (Maughan et al. 2009; Allen et al. 2007). Intercropping is the practice of cultivating two or more crops simultaneously on the same piece of land during the same time span (Guleria and Kumar 2016). It is characterized by rotation and diversification in time and space dimensions (Crusciol et al. 2011; Biabania et al. 2008).

Intercropping is usually carried out in four different and distinct ways. In row intercropping, distinct rows of component crops are clearly identifiable (Crusciol et al. 2012). Row intercropping is carried out either in additive series (no sacrifice of main crop lines) or replacement series (main crop row is reduced for each intercrop row) (Iqbal et al. 2017). Mixed intercropping entails the intercropping system in which seeds of different crops are mixed and sown in blended form in the same row or broadcasted (Iqbal et al. 2018a; Khatiwada 2000). Ultimately, there is no row distinction of component crops in mixed intercropping systems (Agegnehu et al. 2006). In relay intercropping systems, a second crop is sown in a standing crop that has nearly reached the end of its production cycle, prior to harvest (Reda et al. 2005). In strip intercropping, two or more crops are sown in strips wide enough to accommodate many rows, but close enough to facilitate interactions (Li et al. 2001).

Intercropping systems help farmers to exploit the principle of diversity (Ghosh 2004), they are helpful to avoid reliance on a single crop and result in a variety of products of a different nature such as forages, oil and pulses (Iqbal et al. 2018b). Another key advantage associated with intercropping is its potential to increase the land productivity per unit area and the efficient utilization of farm resources (Ahmad et al. 2006; Mucheru-Muna et al. 2010). Cereals intercropping with legumes result in increased resource capture by component crops and improve soil microbial activity along with better efficiency of resource conversion which triggers higher biomass production (Alvey et al. 2003).

In addition, soil fertility is improved when legumes are intercropped with cereal forages (Iqbal et al. 2018c). Cereal-legumes intercropping systems improve nutrient utilization (Ghosh et al. 2006) as different crops have varied root lengths and in this way nutrients are absorbed from different soil horizons (Shivay and Singh 2000; Ghosh

et al. 2007). Intercropping of cereals with legumes also increases the productivity per unit of land area due to the atmospheric nitrogen biological fixation (BNF) that takes place in the root nodules of legumes (Pal and Sheshu 2001). Cereal-legumes intercropping not only increase the primary nutrients (N and P) concentration in roots and shoots of crop plants but also enhance micronutrients absorption. It was reported that in cereal-peanut intercropping systems, there was a 2.5 fold greater concentration of zinc and iron in shoots as compared to their monocropping. Potassium concentration in shoots was also increased, while calcium concentration was decreased in shoots of component crops (Inal et al. 2007).

In forage production, profitability is of the utmost importance and intercropping of cereals with legumes has been reported to increase economic returns. Greater productivity per unit area by sorghum-soybean intercropping systems resulted in 46% higher monetary returns than their sole cropping (Iqbal et al. 2017). In addition to improved nutritional quality, cereal-legumes intercropping systems had greater economic returns owing to a better land-equivalent ratio (LER) and other competitive indices (Hussain et al. 2002).

The objective of this review of sorghum-legume intercropping systems was to synthesize research findings on forage productivity, nutritional quality, competitive performance of component crops and economic viability of row (row-replacement series), mixed (seed blended crops) and strip intercropping systems in comparison to monocropping systems.

## GREEN FORAGE AND DRY MATTER BIOMASS OF COMPONENT CROPS IN INTERCROPPING SYSTEMS

For intercropping legumes with forage sorghum, spatial arrangement is an important factor that needs to be considered because of its effect on the compatibility of component crops (Mutungamiri et al. 2001; Oseni and Aliyu 2010; Iqbal et al. 2018d). Sorghum-cowpea and Sorghum-cluster bean intercropping in a 2:1 row proportion resulted in the highest fresh and dry biomass than other spatial arrangements (Iqbal 2018). When the row proportion of the legume intercrop was increased, agro-qualitative traits of the mixed forage were enhanced but overall biomass

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production was decreased (Surve et al. 2011). Similarly, when maize (*Zea mays* L.) was planted in alternate rows (1:1) with cowpea (*Vigna unguiculata* L.), comparatively better agronomic growth of component crops led to the highest fresh and dry biomass owing to more number of plants per unit land area (Iqbal et al. 2006; Geren et al. 2008). In contrast, Patel and Rajagopal (2001) recommended 5:2 or 4:2 row proportions for intercropping cereal with cowpea. Maize intercropping with peanut in a 50:50 seed-blending ratio gave 38% higher forage yield as compared to other seed-blending ratios. Nitrogen savings from the peanut intercrop was attributed as the possible reason behind the observed higher productivity of the maize-peanut system (Dahmardeh 2013). The overall productivity in sorghum-legumes intercropping systems was increased by 9 to 55% compared to solo sorghum as shown in Table 1.

Along with the spatial arrangements, the choice of component crops is actually the first and foremost step in the design of intercropping systems. Agro-botanical and morphological characteristics of component crops need to be carefully worked out particularly for mixed intercropping systems. It was reported that soybean in mixed intercropping

with sorghum resulted in higher biomass production despite the decrease in the yields of component crops. The improved performance of the mixed cropping system was attributed to better utilization of resources, particularly soil moisture and nutrients (Gare et al. 2009). Similarly, when soybean row arrangement resulted in the greatest mixed forage yield as compared to other spatial arrangements, it was concluded that soybean must be planted at least at a 1:1 ratio with sorghum because legumes yield only half as much as the cereal forages (Wanjari et al. 2005).

An experiment of lima bean intercropping with sorghum determined that green forage yield was increased by 61% with a 80:20 sorghum-legume seed-blending ratio as compared to other blending ratios. Mixed intercropping was reported to be more effective than row intercropping systems in nitrogen transfer from lima bean to sorghum through roots intermingling, which increased mixed forage yield (Reza et al. 2012). However, Ahmad et al. (2007a) found sesbania and cowpea more suitable crops for intercropping with sorghum compared to cluster bean and mungbean. Likewise, Sharma et al. (2009) suggested that cowpea might be intercropped with sorghum for obtaining higher

**Table 1.** Forage biomass production in sorghum-legumes mixed, row (additive and row replacement series), and strip intercropping systems in comparison to solo sorghum under varied pedo-climatic conditions.

Intercropping system	Biomass increment (%)
<b>Mixed intercropping systems</b>	
Sorghum + Cowpea in 100:100 seed ratio (Abusuwar and Ahmed 2012)	18
Sorghum + Lima bean in 100:20 seed proportion (Reza et al. 2012)	13
Sorghum + Guinea grass mixed seeding (Borghi et al. 2013b)	29
Sorghum + Soybean mixed seeding (Fidelis et al. 2016)	28
Sorghum + Cowpea in 70:30 seed proportion (Zamir et al. 2016)	52
Sorghum + Groundnut in 100:100 seed proportion (Maman et al. 2017)	23-30 at subsequent harvests
<b>Row intercropping (additive and row replacement series) systems</b>	
Sorghum + Moth bean in 3-3 row proportion (Ambhore et al. 2008)	39
Sorghum + Cowpea in 2-2 row ratio (Sharma et al. 2009)	28
Sorghum + Cowpea in alternate rows (Makoi and Ndakidemi 2010)	40
Sorghum + Cowpea in 2-1 row ratio (Surve et al. 2012)	55
Sorghum + Cowpea in 30 cm alternate rows (Akhtar et al. 2013)	36
Sorghum + Cowpea in 1-1 row proportion (El-Sarag 2013)	9
Sorghum + Cowpea in 2-1 row ratio (Rathore 2015)	32
Sorghum sown 18 days prior to soybean in 2-1 row ratio (Iqbal et al. 2017)	41
<b>Strip intercropping systems</b>	
Sorghum + Sesbania sown in 45 cm apart double row strips having 15 cm row-row spacing (Ahmad et al. 2007a)	32

forage yields. In contrast, Blade et al. (1991) concluded that cowpea yield in intercropping with sorghum and maize was decreased significantly and suggested to intercrop erect genotypes of cowpea instead of spreading ones.

Cereal-legumes intercropping systems improve water use efficiency as more soil cover prevents evaporation losses, plus varying roots lengths of component crops are able to extract moisture from different soil horizons. Sani et al. (2011) reported that cereal-sorghum row intercropping system (1:1 row ratio) was effective in increasing water use efficiency because it produced more biomass per unit area by using the same quantity of water as compared to their sole cultivation.

Legumes based intercropping systems improve the absorption of macro and micronutrients from the soil along with nutrient use efficiency (NUE) (Li et al. 2003; Crews and Peoples 2004). Intercropping of sorghum and palisade grass (*Urochloa brizantha* L.) in narrow row spacing (0.90 m) yielded a better forage production than wider row spacing, owing to significantly higher NUE (Borghi et al. 2013a). In addition, Baributsa et al. (2008) reported that inter-seeding of red clover with cereals had no adverse effects on biomass production as long as the plant population of clover remained below 75000 plants per hectare.

Weeds compete with crop plants for soil (space, nutrients and moisture) and environmental (light and CO<sub>2</sub> for photosynthesis) growth resources and thus reduce the growth and yield of crops (Chalka and Nepalia 2005; Satheshkumar et al. 2011). Sorghum-legumes intercropping can be a way to reduce the crop-weed competition by reducing weed infestations (Reda et al. 2005). Intercropping reduces weed populations by reducing the uncovered space available to be occupied by weeds. It was reported that sorghum intercropping with food legumes suppressed witch-weed (*Striga hermonthica*) density considerably. In addition, forage sorghum was particularly susceptible to weed competition before it reached knee height, but legumes intercropping reduced weed infestation, which enhanced its growth (Khan et al. 2007).

While legumes meet some of their N requirement through biological nitrogen fixation (BNF), it should be recognized that BNF takes time to become fully functional (Pal and Sheshu 2001). Before the BNF process begins to supply nitrogen, legumes obtain their entire supply from the soil solution and this may create an intercrop competition for nutrients. Thus, it was found that delaying legumes sowing

for a few days after cereal cultivation helped to improve establishment of cereal forages as compared to simultaneous sowing of component crops (Iqbal et al. 2017). At the early growth stages, intercrop competition can drastically reduce the forage yield of component crops. If early competition is avoided by planting intercrops at different dates, then forage yields are reported to increase significantly (Borghi et al. 2013b). However, there is a dire need to investigate further the optimized delayed sowing of component crops to achieve maximum productivity per unit land area.

While some annual forage crops can reach high biomass yields, these may not be as effective in reducing soil erosion as much as some perennial species. In order to increase biomass production and reduce soil erosion, forage sorghum was inter-seeded with alfalfa under different planting patterns. Intercropping resulted in a 38% higher dry matter yield than sole cropping. Sorghum intercropping with alfalfa also resulted in 1 t·ha<sup>-1</sup> of soil erosion on slopes in comparison to 14 t·ha<sup>-1</sup> under sorghum monoculture. More plants per unit land area in intercropping systems tend to improve ground cover and reduce the extent of exposed soil resulting in less soil erosion (Buxton et al. 1998).

In intercropping, different row arrangements will result in different levels of light interception, soil moisture and nutrients with respect to the azimuthal direction of leaves. These factors were evaluated in a field investigation where soybean was intercropped with maize in East-West rows under dry conditions (Lesoing and Charles 1999). It was observed that light interception was minimized when the leaf azimuth was parallel to the row direction. A linear relationship was also observed between the leaf azimuth and yield which in turn was affected by the row orientation. It was suggested that in sorghum-cowpea intercropping, the direction of rows of component crops is an important variable that needs to be investigated further under varied agro-ecological and agro-environmental conditions (Karanja et al. 2014).

Under adverse environmental conditions, sorghum-legume intercropping resulted in improved biomass production compared to mono cropping (Iqbal et al. 2017). Sorghum-cactus pear intercropping showed higher water use efficiency under severe drought because of lower evapotranspiration, which resulted in improved biomass production (Lima et al. 2018). Similarly, Diniz et al. (2017) reported that sorghum was dominated by cactus pear in intercropping indicating a higher competitive capacity of

cactus pear compared to sorghum. However, in intercropping overall biomass was increased in comparison to monocultures due to lesser exposed ground area which improved moisture conservation under the high temperatures. Thus, it was recommended to intercrop sorghum with drought-hardy crops like cactus pear in arid regions that experience prolonged spells of drought and high temperatures.

## PHYSIOLOGICAL RESPONSE OF COMPANION CROPS IN CEREAL-LEGUMES INTERCROPPING SYSTEMS

Different physiological growth parameters including leaf area index, leaf area duration, crop growth rate and net assimilation rate have been identified as reliable indicators to predict final yields (Rathore 2015; Iqbal et al. 2016). When sorghum was intercropped with legumes (cowpea, cluster bean, mung bean and sesbania) in double row strips, higher leaf area resulted in the highest green forage yield and dry matter biomass (Ahmad et al. 2007a).

The leaf area index of component crops was decreased in intercropping in comparison with sole cropping but overall higher leaf area per unit land area caused a significant increase in mixed forage yield (Geren et al. 2008). Similarly, row intercropping of sorghum and soybean in 30 cm spaced rows resulted in significantly lower physiological growth as indicated by leaf area duration, leaf area index, crop growth rate and net assimilation rate. In contrast, Refay et al. (2013) concluded that sorghum-cowpea intercropping in 2:2 row replacement series resulted in the highest leaf area, which led to highest dry matter accumulation. It was also reported that when soybean sowing was deferred for 15 days, then forage sorghum recorded comparatively better physiological growth probably owing to a lower competition for growth resources at the earlier growth stages (Iqbal et al. 2016).

Delayed sowing of one of the component crops has shown a positive influence on the physiological growth of both crops. Akram and Goheer (2006) reported that concurrent cereal-legumes intercropping resulted in severe competition for growth resources and that the growth of cereal was negatively affected. In comparison with cereals, legumes (cowpea and rice bean) suffered relatively more losses in forage yield (Ayub et al. 2004; Ayub and Shoaib 2009). Row intercropping of sorghum with black gram in a 1:1 row ratio resulted in enhanced growth parameters including leaf

area indices and crop growth rate, while yield was significantly increased as compared to sorghum monoculture (Rathore et al. 2012). However, in cereal-legumes intercropping systems, comparatively taller cereals render a shading effect that reduced the physiological growth of leguminous intercrops, which called for the need to optimize the spatial arrangement and canopy structure of component crops.

## COMPETITIVE PERFORMANCE OF COMPONENT CROPS IN CEREAL-LEGUMES INTERCROPPING SYSTEMS

In intercropping systems, competition is an important factor that needs to be considered to determine the compatibility of the component crops. When intercropping cereal forages with legumes, spatial arrangements are important to determine the degree of inter and intra species competition (Iqbal et al. 2016; Iqbal et al. 2018a). Sharma et al. (2009) reported that intercropping of cowpea with multi-cut sorghum in 2:2 row proportions increased green forage yield ( $43 \text{ t}\cdot\text{ha}^{-1}$ ), aggressivity index (AI) and LER as compared to 1:1, 1:2 and 2:1 row proportions. Similarly, new competitive indices such as yield loss (YL) and actual intercropping advantage (AIA) in intercropping replacement series may suggest the most biologically and economically suitable cropping pattern and spatial arrangements. For instance, maize in intercropping with cowpea showed the highest values of AIA and significantly lower YL values as compared to their respective monocultures (Takim 2012).

Sorghum-cowpea and sorghum-cluster bean intercropping planted in 1, 2 and 3 row strips revealed that the greatest green forage yield and LER of 1.89 was obtained with sorghum and cowpea sown in 3 row strips (Hussain et al. 2002). Likewise, maize-cluster bean intercropping in 3:3 row proportions recorded the highest LER compared to 5:2 and 4:2 row ratios (Patel and Rajagopal 2001). Rathore (2015) found that sorghum-cowpea intercropping in 2:2 and 1:1 row ratios resulted in the highest LER. When faba bean was intercropped with maize, a positive effect on yield and LER was observed (Li et al. 2001), while mustard-pea and lentil-gram intercropping resulted in significantly greater yield losses of component crops as indicated by a higher actual yield loss (AYL) (Banik et al. 2000). On the basis of these findings, it may be suggested that cereal-legume

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intercropping systems are more resource complementary than legume-legume intercropping systems.

When forage sorghum was intercropped with cowpea, cluster bean and mungbean under 30, 45 and 75 cm spaced single, double and four row strips, sorghum remained the dominant crop in terms of resources competition. Forage sorghum showed higher values of competitive indices such as relative competitive ratio (RCR), crowding coefficient (K) and aggressivity index (AI) in intercropping with cowpea (Oseni 2010). All these competitive indices showed that when forage sorghum was cultivated in association with forage legumes, sorghum continued to remain dominant in terms of utilization of growth resources and that legumes showed a recessive behavior (Dapaah et al. 2003).

An intercropping trial of sorghum and cowpea under different row proportions showed that a 2:1 row proportion gave a better land equivalent ratio (LER) as compared to other planting patterns (Oseni 2010). Similarly, cereal-common vetch mixed cropping in 65:35 seed ratios outperformed other mixtures by recording the highest LER and the lowest AYL (Dhima et al. 2007). When mash (*Vigna mungo* L.) was intercropped with maize in 90 cm spaced double row strips, intercropping resulted in a significantly higher LER (Ehsanullah et al. 2011). Similarly, when maize and cowpea were sown in mixtures of 100:100, 75:25, 50:50, and 25:75, LER for the intercropping systems was higher than 1 indicating an intercropping advantage compared to monoculture crops (Dahmardeh et al. 2010). Thus, it may be suggested that competitive performance of component crops in intercropping systems vary depending upon variety, type of intercropping, soil fertility and agro-climatic conditions.

Another important aspect that needs to be considered is the yield stability of cereals-legumes intercropping systems, especially under varying climatic and environmental conditions. A field study revealed that cereal-bean intercropping systems harvested at different times resulted in higher biomass production than monocropping, indicating greater system productivity per unit of land area (Gare et al. 2009). Greater yield stability (YS) was recorded in maize-cowpea as compared to maize-soybean intercropping system indicating a potential greater system resiliency under varying environmental conditions (Dapaah et al. 2003). Similarly, pea in intercropping with rye (*Secale cereale* L.) in 1:1 row ratio gave higher yield stability than other monocultures (Karpenstein-Machan and Reinhold

2000). In addition, soybean-sugarcane intercropping in 1:2 row proportions recorded significantly higher yield stability than other planting patterns (Luo et al. 2016). However, further in-depth research needs to be done in order to increase yield stability of sorghum-legume intercropping systems under varying pedo-climatic conditions.

## AGRO-QUALITATIVE ATTRIBUTES OF FORAGE IN CEREAL-LEGUMES INTERCROPPING SYSTEMS

Although cereal forages have obtained a central position in the ruminant's feed because of their higher biomass production (Iqbal et al. 2018e), cereals are considered poor on the animal nutrition scale as shown in Table 2. One way to increase the quality of forage is to intercrop the cereal forages with legumes such as cowpea, cluster bean and soybean because legumes contain almost double the quantity of protein than cereals (Ghanbari-Bonjar and Lee 2003). Intercropping of cereal forages with legumes reduces the amount of protein supplementation needed for lactating animals.

Crop mixtures result in a variety of agronomic benefits (Ibrahim et al. 2012) along with improved crude protein content. In a row replacement series, Ahmad et al. (2007b) concluded that sorghum-cowpea and sorghum-sesbania produced better results in terms of green forage yield and quality. When maize was intercropped with berseem clover, forage yield and quality was improved, especially with respect to the protein concentration increasing from 19 to 27 g·kg<sup>-1</sup> (Javanmard et al. 2009). Similarly, in sorghum-soybean intercropping crude protein content in leaves of the soybean intercrop was improved by 25 g·kg<sup>-1</sup> than solo soybean; however it was decreased in stems of the soybean intercrop (Redfearn et al. 1999).

Legumes tend to improve the quality and nutritional value of mixed forage due to their higher protein content. It was found that cereal-legumes (faba bean, lupin and pea) mixed cropping resulted in a significant increase of crude protein of mixed forage up to 132 g·kg<sup>-1</sup> of dry matter (Strydhorst et al. 2008). Because cereals are higher in lignin content than legumes, grass-legumes mixed cropping was instrumental to increase the acid detergent lignin (ADL), decrease the neutral detergent fiber (NDF) and improve the crude protein content, which is important to improve the productivity of lactating animals (Sleugh et al. 2000).

**Table 2.** Nutrition quality of mixed forage in sorghum-legumes mixed, row (additive and row replacement series) and strip intercropping systems in comparison to solo sorghum under varied pedo-climatic conditions.

Intercropping system	Protein (%)	Fiber (%)
<b>Mixed intercropping systems</b>		
Sorghum + Mungbean in 100:100 seed proportion (Khan et al. 2005)	+10.30	-3.29
Sorghum + Cowpea in 100:100 seed proportion (Basaran et al. 2017)	+8.40	-
Sorghum + Lablab in 50:50 seed proportion (Abusuwar and Al-Solimani 2013)	+1.55	-0.78
Sorghum + Cowpea in 25:100 seed proportion (Contreras-Govea et al. 2013)	+12.68	-4.80
Sorghum + Lablab mixed seeding (Juntanam et al. 2013)	+8.05	-2.62
Sorghum + Cowpea + Cluster bean in 100:100 seed ratio (Akhter et al. 2013)	+9.21	-6.37
<b>Row intercropping (additive and row replacement series) systems</b>		
Sorghum + Lablab in alternate rows (Ishiaku et al. 2016)	+3.98	-1.08
Sorghum + Cowpea in 2-2 row proportion (Surve et al. 2012)	+12.26	-2.50
Sorghum + Cluster bean in 2-1 row proportion (Pathak et al. 2013)	+11.68	+5.76
Sorghum sown 15 days after Soybean in 2-2 row ratio (Iqbal et al. 2017)	+0.97	-4.84
<b>Strip intercropping systems</b>		
Sorghum + Sesbania sown in 45 cm apart double row strips having 15 cm row-row spacing (Ahmad et al. 2007b)	+9.35	-2.20
Brown midrib (BMR) sorghum + Lablab in alternate strips (Colbert et al. 2012)	+8.40	-20.08

+ and - indicate increment and depreciation, respectively.

It is important to learn about the factors and processes that are involved in increasing green forage yield as well as the quality attributes of forages in cereal-legumes intercropping systems. Legumes such as cowpea, cluster bean and soybean have the ability to fix atmospheric nitrogen, which helps to fulfill a greater part of their nitrogen requirement (Pal and Sheshu 2001). In this way more nitrogen becomes available to cereal forages grown in intercropping with forage legumes. Crude protein of forages is reportedly influenced by nitrogen availability and by nitrogen contribution from legumes leading to increased crude protein content of forage sorghum intercrops (Ahmad et al. 2007a). Legumes also play a role in increasing fertilizer use efficiency (FUE) resulting in more biomass production and improved agro-quality attributes. The reason behind the improved quality forage was attributed to a higher FUE (elemental NPK 80:40:20 kg-ha<sup>-1</sup>) as companion crops made better absorption and efficient utilization of applied fertilizers (Sharma et al. 2000).

The seed proportion of component crops in cereal-legumes intercropping systems tend to influence forage quality of component crops in mixed forage. In a field trial, cowpea was intercropped in varying seed rates of 25, 50, 75, and 100% of the recommended seed rate with sorghum. The results showed that the 100% and 75% of recommended seed rate of cowpea gave the highest protein content than other mixed forage ratios

(Khan et al. 2005). The obvious reason for the increase of crude protein in mixed intercropping was the higher share of protein contributed by legumes and therefore the 100% legume seed rate was recommended for mixed intercropping with cereals.

Legumes intercropping with cereals improve forage quality by increasing protein and decreasing fiber content as fiber is considered to be an anti-nutritional factor. Sorghum-cluster bean mixed intercropping was found beneficial with respect to crude protein, ether extractable fat and total ash content. Blended seeding of sorghum and cowpea produced significantly higher crude protein (14.9%) and ash (10.3%), and comparatively less fiber as compared to monocropping (Akhtar et al. 2013). Similarly, sorghum-soybean intercropping in a row replacement series increased the agro-qualitative traits of forage sorghum probably due to nitrogen contributions from legume intercrops resulting in increased crude protein, ether extractable fat and total ash contents, while crude fiber was decreased considerably (Iqbal et al. 2016). Thus, sorghum-legumes intercropping might be suggested due to its potential to improve crude protein, fat and ash of mixed forage while decreasing crude fiber content. Because legumes increase forage quality but decrease total biomass production, field investigations must be conducted to optimize cereals-legumes planting ratios in intercropping systems.

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## ECONOMIC PERFORMANCE OF SORGHUM-LEGUMES INTERCROPPING SYSTEMS

All agricultural activities revolve around economics and it becomes more important when small-scale farmers intend to meet their diverse needs from the same piece of land (Ghosh 2004; Surve et al. 2012). Iqbal et al. (2016) reported that in sorghum-soybean row-replacement intercropping systems, the highest benefit-cost ratio (BCR) and monetary benefits (57% higher) were recorded when soybean sowing was delayed for 15 days. It was suggested that in order to obtain full benefits from intercropping, delayed sowing of one of the component crops must be considered. Another experiment assessed the monetary benefits and BCR rendered by sorghum-legume intercropping systems and the results revealed that all agronomic parameters of forage sorghum were significantly enhanced when sorghum was intercropped with groundnut in a 1:1 row proportion, while a 2:2 row proportion gave the maximum monetary returns and benefit-cost ratio (BCR) (Langat et al. 2006). Similarly, sorghum and guinea grass mixed seeding under tropical conditions resulted in 2.4 times higher monetary returns compared to solo sorghum, while delayed sowing of guinea grass recorded a significant decline in revenue (Borghetti et al. 2013b).

Khan et al. (2005) reported that sorghum intercropping with legumes such as cowpea and mungbean increased total biomass production per unit of land area, which was attributed to legume N fixation by cowpea and mungbean. It was also concluded that intercropping of sorghum with legumes resulted in substantially lower biomass of weeds, which increased sorghum yield, economic returns and the benefit-cost ratio (BCR). Dual purpose sorghum cultivars were intercropped with guinea grass and palisade grass (both perennial forages) simultaneously and as top dressing. The results revealed that biomass production was almost doubled in intercropping systems compared to sorghum monoculture. The forage sorghum-guinea grass intercropping system was also superior in terms of monetary returns (Borghetti et al. 2013b). Intercropping of two common cultivars of soybean at 100:0, 50:50, 25:75 and 0:100 ratios revealed that seed blending in the 50:50 ratio increased total biomass production, which resulted in improved economic returns (Biabani et al. 2008).

Sorghum-legume intercropping is an effective and strategic approach for reducing the risk of crop failure and subsequent economic losses under adverse pedo-climatic conditions. Legumes were less affected by prolonged dry spells compared to cereals, which resulted in higher biomass production and economic returns (343%) due to the improved rainfall infiltration (164%) than their monocultures (Rusinamhodzi et al. 2012). Sorghum-pigeon pea mixed intercropping recorded higher biomass, economic returns and ultimately reduced the risk associated to farming under adverse agro-climatic conditions by minimizing the variability in productivity and economic returns (Rao and Singh 1990). On marginal soils, cowpea and groundnut performed better than soybean owing to better utilization of environmental and soil resources and thus cereal-cowpea mixed seeding was suggested to reduce the risk of a sharp decline in economic returns (Kermah et al. 2017).

## CONCLUSION

To improve sustainability and resiliency, traditional farming systems need to be improved to minimize adverse environmental impacts from their farming practices and to reduce farmer dependence on government subsidies. Forage sorghum-legumes intercropping systems result in improved production efficiency, complementary use of resources, weed control, better nutritional quality and higher economic returns. However, component crops record a significant decrease in biomass production owing to competition for finite resources which calls for optimization of sowing time, spatial arrangements and proportionate share of component crops in mixed and row intercropping systems. Furthermore, delayed sowing of component crops might also be investigated to avoid competition at the earlier growth stages and to improve the production efficacy of sorghum based intercropping systems.

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